Advances in Forestry Letters, Volume 5 2016 www.afl-journal.org
doi: 10.14355/afl.2016.05.001

Canopy, Understorey Leaf Phenology and Seasonality in Tropical Dry Forest, Southern India

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Abstract

This study aimed to compare the timing of leaf phenology of canopy and understorey trees with rainfall and temperature in bhadra wildlife sanctuary. Leaf initiation in canopy trees begins in February and peaks in April, in understorey trees begins in February peaks in March with a varying number of species. Leaf expansion starts from February till July, as expansion to full leaf takes more time from summer to onset of rain both in canopy and understorey trees. Leaf senescence begins in November and peaks in December and January in both years with varying number of species. Spearman's rank correlation analysis was used to examine how variations in rainfall and temperature influenced deviations in the peaks and troughs of phenology cycles. We tested for the occurrence of seasonal phenological patterns within canopy and understorey trees using circular statistics. Seasonality of leafing phenophases in canopy and understorey trees is strongly seasonal. As understorey leaf initiation begins first latter in canopy trees with a difference of 13-14 days, when canopy trees are in leaf less or leaf absence period, whereas leaf expansion and leaf senescence takes place early in canopy trees, with a difference of 2 and 4 days. Absence of leaf peaks in the middle of the March in canopy and understorey trees, with a difference of 3-5 days.

Keywords

Canopy Trees; Dry Forest; Leaf Phenology; Understorey Trees; Seasonality; Rainfall; Temperature

Introduction

Information on phenological patterns is essential to understand ecological and biological process of trees and organisms that depend on trees. Phenology refers to seasonal biological life stages driven by environmental factors, and is considered to be a sensitive and precise indicator of climate change (Lieth 1974; Schwartz 1998; Menzel and Fabian 1999; Beaubien and Freeland 2000). Therefore, phenology has emerged recently as an important focus for ecological research (Schwartz 1999; Menzel 2001).

Phenology affects nearly all aspects of ecology and evolution as phenology at the population or ecosystem level is ultimately a product of selection acting on variation among individuals. (Jessica *et al.*, 2010)

It is important to explain the distinction between phenology and seasonality. Seasonality refers to temporal patterns of abiotic variables occurring at annual or sub-annual timescales. Phenology and seasonality are complementary aspects of ecosystem function that interact. (Schwartz 1996).

Tropical dry forests form the largest component of the world forest cover. Yet they are relatively less studied and understood tropical forest communities (Murphy and Lugo 1986).

While some earlier studies have described the general phenological aspects of leafing, flowering and fruiting in tropical tree species (Borchert 1983; Daubenmire 1972; Frankie 1974; Opler 1980; Putz 1979; Singh and Singh 1992; Sun 1996).So it is important to understand how structural and compositional differences in foliar phenology will affect the ecosystem processes. Quantification between plant strata (canopy and understorey) in the tropical forest is critical to accurate forecasting of future climate scenarios. Seasonal variation in irradiance also occurs in nature

above forest canopies because of changes in cloud cover, day length and solar angle. (Wright and van Schaik 1994)

There are many previous phenological studies in forest ecosystems of Central Himalaya (Ralhan 1985a, b; Sundriyal 1990) and north eastern India (Boojh and Ramakrishnan 1981; Shukla and Ramakrishnan 1982; Kikim and Yadava 2001) southern India (Sundarapandian 2005; Singh and Kushwaha 2004; Murali and Sukumar 1993; Prasad and Hegde 1986; Bhat 1992; Nanda *et al.* 2010; 2011).

Yet our understanding of leafing patterns and their underlying determining mechanisms is a key to assessing the health of the forest, as both canopy and understorey trees leafing phenophases timing and duration are separate, predictions are therefore needed to be evaluated separately as it's difference between forest types (Nanda *et al.* 2012; 2015). In tropical trees, leaf phenology is important because it reflects the influence of evolution and environment on plant characteristics, and in turn has substantial implications for plant functioning. (Reich 2004)

Phylogeny may be an especially powerful approach for understanding phenology because it provides a simple method to integrate species differences across multiple traits, which may have complex underlying physiological pathways. (Pau *et al.*, 2011)

The lifeform (canopy and understorey) phenological patterns of tree species in tropical forest are rather less. Therefore, the present study aims to analyse the leafing phenological pattern in canopy and understorey tree species with available meteorological data the following questions were addressed.

1. How to investigate the relationship between rainfall and temperature in canopy and understorey tree species leaf phenology?

2. How to know the strength of seasonality in canopy and understorey trees leaf phenology?

3. How duration of leafing phenology varies based on seasonality?

Materials and Methods

Study Area

The study was conducted in Umblebailu (13°.46'to 13°52' N, 75°36'to 75°.42'E) region of Bhadra wildlife sanctuary located in Chikmagalur and Shimoga districts (13°25' and 13°50′ N, 75°15' and 75°50' E) of Karnataka, Central Western Ghats. The terrain is gently undulating with valleys and steep hillocks. Detailed geological account of the sanctuary is given by (Parameshwar 2001). The altitude varies from 750 to 2100 above mean sea level. Climatic conditions (rainfall and temperature) data for the study area was collected from meteorological station, Bhadra River Project. Average annual rainfall and temperature pattern during the study period (Fig. 1).

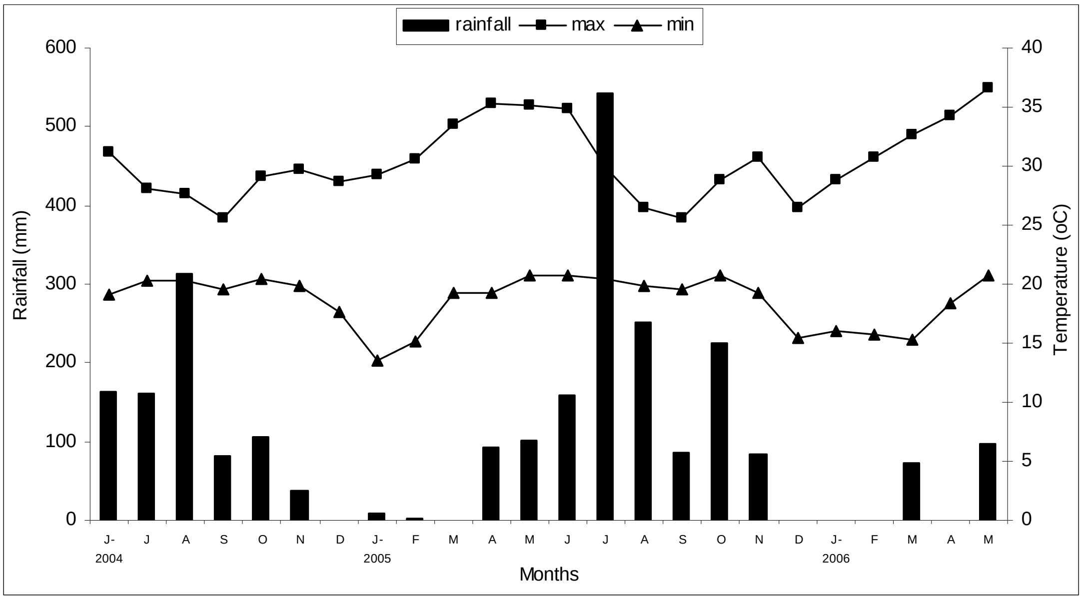

FIG.1 MONTHLY RAINFALL, MEAN MONTHLY MAXIMUM AND MINIMUM TEMPERATURE (°C) AT DRY DECIDUOUS FOREST IN BHADRA WILDLIFE SANCTUARY DURING THE STUDY PERIOD.

Vegetation

Vegetation of the sanctuary varies from dry deciduous to evergreen forests through moist deciduous type depending on the precipitation pattern. According to Champion and Seth (1968) the dry deciduous forests are classified as 'southern dry mixed deciduous forests'.

Methods

Woody stems above 20 cm diameter at breast height with clearly visible canopy and understorey trees were marked with a unique tag number on either side of the transect about 2 Km. A total of 157 individuals of 22 canopy tree species and 120 individuals of 24 understorey tree species these marked individuals were monitored for leafing phenophases once in month from June 2004 to May 2006. (Table-1) Leafing phenophases includes four different stages such as 1. Leaf less / absence of leaf, 2. Leaf initiation / leaf budding, 3. Leaf expansion and 4. Leaf senescence / falling of leaf.

TABLE.1. TREE SPECIES STUDIED, LIFE FORM (CANOPY, UNDERSTOREY) AND NUMBER OF INDIVIDUALS, DRY DECIDUOUS FOREST, BHADRA WILDLIFE SANCTUARY, KARNATAKA, INDIA.

Species	Life form - Canopy/ Understorey	Number of Individuals
1.**Anacardiaceae**		
a. *Lannaea coromandelica* (Houtt.) Merr	Canopy	15
b. *Semecarpus anacardium* L.f.	Understorey	06
2. **Annonaceae**		
a. *Polyalthia cerasoides* Hk.f.&T.	Understorey	03
3.**Apocynaceae**		
a. *Holarrhena antidysenterica* wall.	Understorey	07
b. *Wrightia tomentosa* R.&S.	Understorey	03
c. *W. tinctoria* R.Br.	Understorey	06
4.**Bignoniaceae**		
a. *Kigelia pinnata*, DC.	Canopy	03
b. *Dolichondron falcatum* Seem.	Understorey	02
5.**Bombaceae**		
a. *Bombax malabaricum* DC.	Canopy	08
6.**Caesalpiniaceae**		
a. *Acrocarpus fraxinifolius* W.	Canopy	02
b. *Bauhinia malabarica* Roxb.	Understorey	05
c. *Cassia fistula* L.	Understorey	03
d. *Hardwickia binata* Roxb.	Understorey	03
7.**Celastraceae**		
a. *Cassine glauca* Roxb. Kuntze	Understorey	07
8. **Combretaceae**		
a. *Anogeissus latifolia* Wall.	Canopy	10
b. *Terminalia bellerica* Roxb.	Canopy	05
c. *T. chebula* Retz.	Canopy	04
d. *T. paniculata* Roth.	Canopy	13
e. *T. tomentosa* W. & A.	Canopy	12
9.**Ebenaceae**		
a. *Diospyros melanoxylon* Roxb.	Understorey	02
b. *D. montana* Roxb.	Understorey	09
10.**Flacourtiaceae**		
a. *Casearia esculenta* Roxb.	Understorey	04

11. **Lecythidaceae**		
a. *Careya arborea* Roxb.	Understorey	10
12.**Lythraceae**		
a. *Lagerstroemia lanceolata,* Wall.	Canopy	12
b.*L. parviflora,* Roxb.	Understorey	06
13.**Meliaceae**		
a. *Melia dubia* Hiern.	Canopy	04
14.**Mimosae**		
a. *Albizzia odoratissima* Benth.	Canopy	04
b. *Albizzia lebbeck* Benth.	Understorey	04
15.**Moraceae**		
a. *Ficus benghalensis* L.	Canopy	03
b. *F. infectoria* Roxb.	Canopy	02
c. *F. Tsiela* Roxb.	Canopy	02
16.**Papilionaceae**		
a. *Butea monosperma* (Lam.) Taub.	Understorey	06
b. *Dalbergia latifolia* Roxb.	Canopy	06
c. *Dalbergia lanceolaria* Roxb.	Understorey	03
d. *Pterocarpus marsupium* Roxb.	Canopy	06
17. **Rhamnaceae**		
a. *Catunaregam spinosa* (Thunb.) Tirven.	Understorey	08
b. *Ziziphus xylopyrus* Willd.	Understorey	04
18. **Rubiaceae**		
a. *Haldina cordifolia* (Roxb).Ridsd.	Canopy	10
b. *Hymenodictyon orixense* (Roxb.) Mabb.	Understorey	05
c. *Mitragyna parviflora*, Korth.	Canopy	10
19. **Rutaceae**		
a. *Chloroxylon swietenia* DC.	Understorey	03
20. **Sapindaceae**		
a. *Schleichera oleosa* (Lour.) Oken.	Canopy	06
21.**Sapotaceae**		
a. *Bassia latifolia* Roxb.	Understorey	08
22. **Stericuliaceae**		
a. *Pterospermum diversifolium* Blume	Understorey	03
23.**Verbenaceae**		
a. *Tectona grandis* L.f.	Canopy	18

Each stage in leaf phenology was scored on a 0 to 100 per cent, viz. 0 = No leaves; 1 = 1–25 percent of leaves present; 2 = 26–50 percent of leaves present; 3 = 51–75 percent of leaves present; and 4 = 76–100 percent of leaves present (Mclaren and Mcdonald 2005).

The marked individual species were identified using various regional floras (Gamble and Fischer 1998; Saldhana 1996; Yoganarasimhan 1990; Ramaswamy 2001; Neginhal 2004).

Statistical Analyses

We performed Spearman's rank correlation to establish the relationship between frequency of species responding to leafing patterns of canopy and understorey trees during corresponding and 1-3 month lag periods, amount of total rainfall, mean maximum and minimum temperature received in a month were computed using procedures given by Zar (2007).

Seasonality is defined as repeated occurrence of a given event in a cyclic fashion. The question answered in this section includes: a) Are the different phenophases are cyclic in canopy and understorey trees? b) How strong is cyclicity in a given event? We calculated the Rayleigh's Z which tests significance of cyclicity in a given phenophase.

Hypothesis tested is

H_0 = the given phenophase is seasonal or cyclic

H_A = the given phenophase is not seasonal.

We used statistical software "*STASTIXL*," a package for spreadsheets to estimate seasonality in the data. We converted the day of observation in a given month to angles and used these angles and number of species in a given month in a given phenophase to estimate Rayleigh's Z. Mean vector **r** has no units and may vary from 0 (when phenological activity is distributed uniformly through out the year) to 1 (when phenological activity is concentrated around one single date or time of year), indicates the strength of the seasonality. (Morellato et al, 2000; Zar 2007)

Results

Leaf Less / Absence of Leaf Phenology

In canopy and understorey trees leaf less phase begins in the month of January with a peak in February and March in the first year, whereas in the second year leaf less starts one month early in December with a peak in February and March. (Fig. 2)

In canopy trees, Leafless period is negatively significant to rainfall during corresponding months (r_s = -0.44, p<0.03), one month lag (r_s = -0.56, p<0.004), and has a strong negative influence during two month lag (r_s = -0.66, p<0.0008). In understorey species, leaf less duration is not significant to rainfall with corresponding months. During one month lag (r_s = - 0.58, p<0.003) negatively significant and had strong negative influence during two month lag period (r_s = - 0.63, p<0.001). (Fig. 2) Maximum temperature has no significant influence during corresponding as well as time-lag periods in canopy as well as understorey trees. But in canopy trees minimum temperature during corresponding month is negatively significant (r_s = -0.61, p<0.001) and as a strong negative influence during one month lag period (r_s = -0.76, p<0.00001) and two month lag period is negatively significant (r_s = -0.51, p <0.001). In understorey trees minimum temperature during corresponding month (r_s = -0.47, p<0.01) is negatively significant and one month lag period had strong influence (r_s = -0.70, p<0.0001), and two month lag period is negatively significant (r_s = -0.61, p <0.002). (Fig. 3)

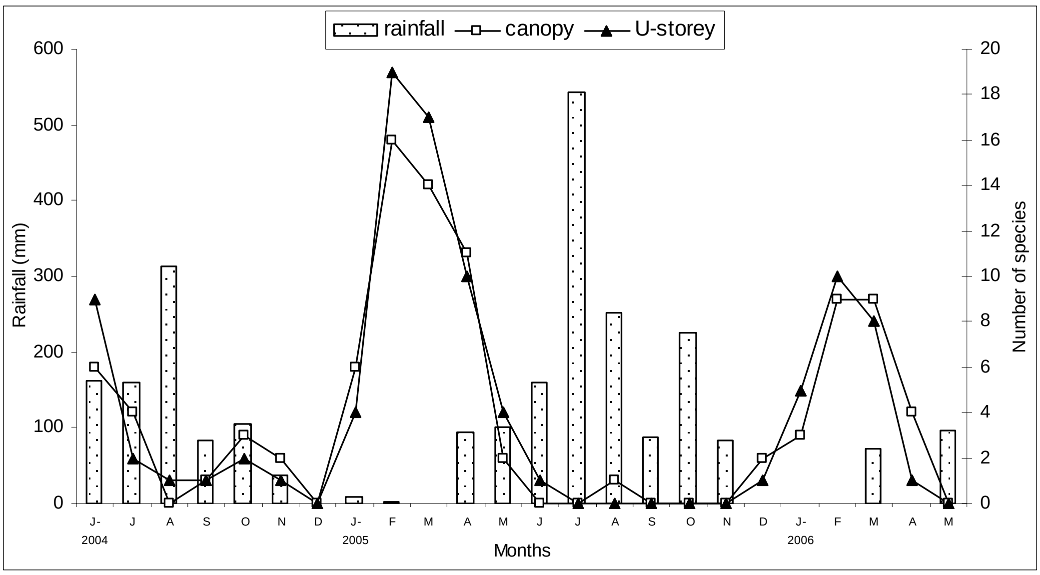

FIG. 2: LEAF LESS / ABSENCE OF LEAF PHENOLOGY IN CANOPY AND UNDERSTOREY TREES WITH AVERAGE MONTHLY RAINFALL IN BHADRA WILDLIFE SANCTUARY.

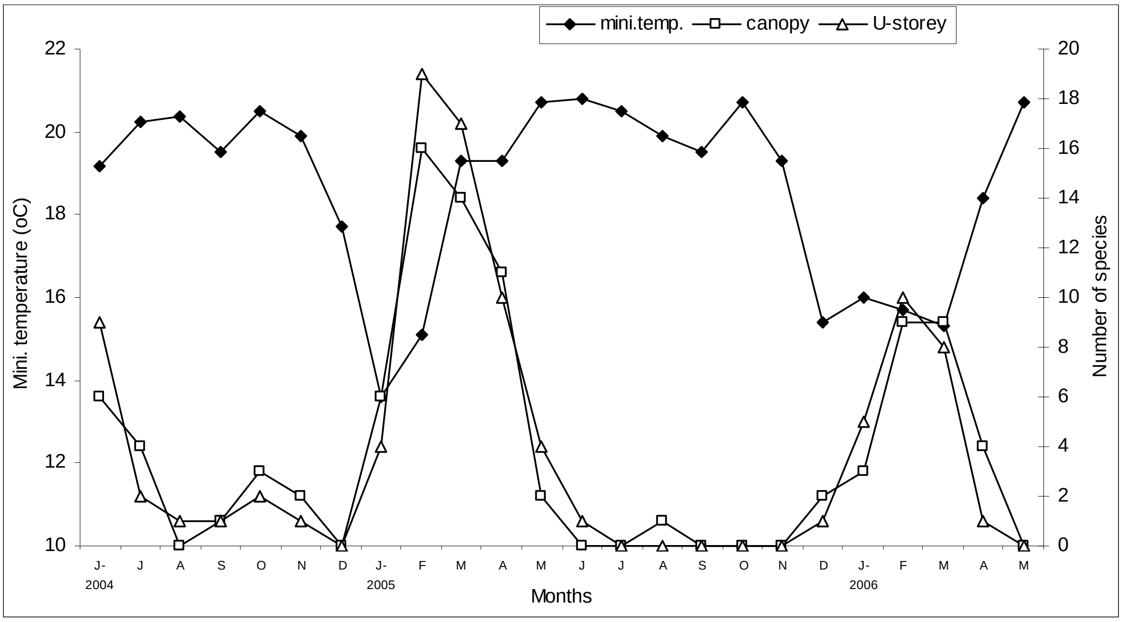

FIG. 3: LEAF LESS / ABSENCE OF LEAF PHENOLOGY IN CANOPY AND UNDERSTOREY TREES WITH AVERAGE MINIMUM TEMPERATURE IN BHADRA WILDLIFE SANCTUARY.

Leaf Initiation / Leaf Bud Phenology

In canopy and understorey trees leaf initiation begins in February and peaks in April and March with a varying number of species in both years. (Fig. 4).

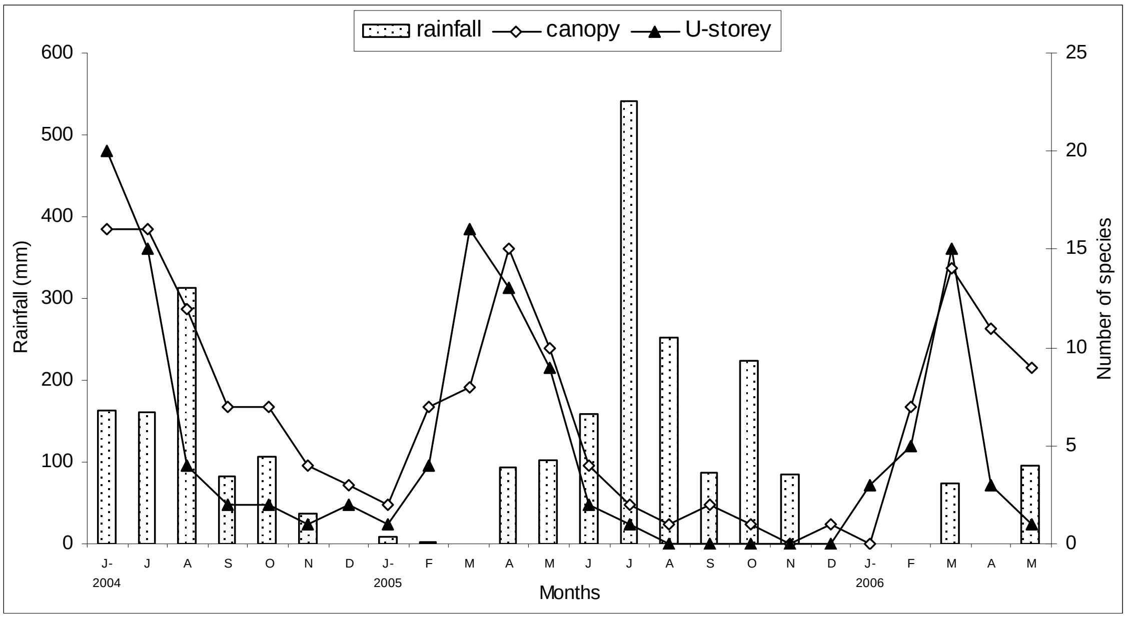

FIG. 4: LEAF INITIATION / LEAF BUDDING PHENOLOGY IN CANOPY AND UNDERSTOREY TREES WITH AVERAGE MONTHLY RAINFALL IN BHADRA WILDLIFE SANCTUARY.

In canopy trees, leaf initiation is not significant to rainfall during corresponding and one month lag period, negatively significant during two month (r_s = -0.50, p<0.01) and has a strong negative significance during three month lag period (r_s = -0.70, p<0.0003). Rainfall has no significant influence during corresponding months. While during one month lag (r_s = -0.42, p<0.04) two month lag (r_s = -0.66, p<0.0007) and three month lag (r_s = -0.59, p<0.004) has a negative significant influence in understorey trees (Fig. 4). Maximum temperature has positive influence (r_s = 0.40, p<0.03) during corresponding months and one month lag period (r_s = 0.41, p<0.05) in canopy trees. Maximum temperature is positively significant during corresponding month (r_s = 0.43, p<0.03) and has no influence during lag periods in understorey trees. (Fig. 5) In canopy trees minimum temperature is not significant during

corresponding and one month lag period, and negatively significant during two months (r_s = - 0.68, p<0.0004), and has a significant strong negative influence during three month lag period (r_s = -0.81, p<0.0000006). Where has in understorey trees minimum temperature had no influence during corresponding months. One month (r_s = -0.56, p<0.004), three month (r_s = -0.64, p<0.001) has a significant negative influence and two month lag period has a strong negative influence (r_s = -0.73, p<0.00008). (Fig. 6)

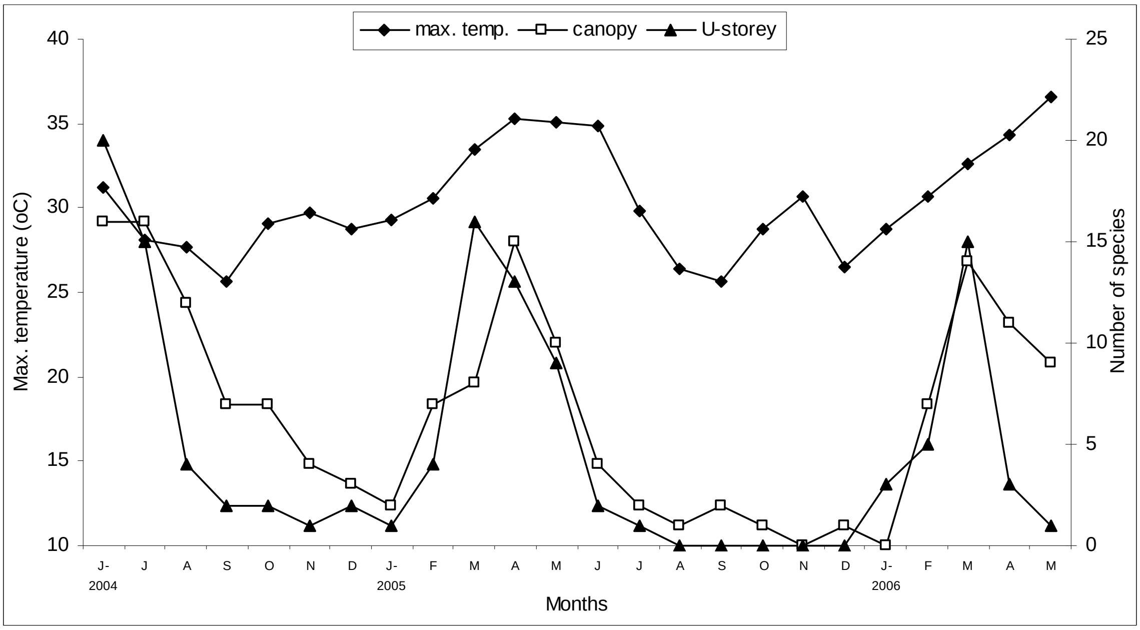

FIG. 5: LEAF INITIATION / LEAF BUDDING PHENOLOGY IN CANOPY AND UNDERSTOREY TREES WITH AVERAGE MAXIMUM TEMPERATURE IN BHADRA WILDLIFE SANCTUARY.

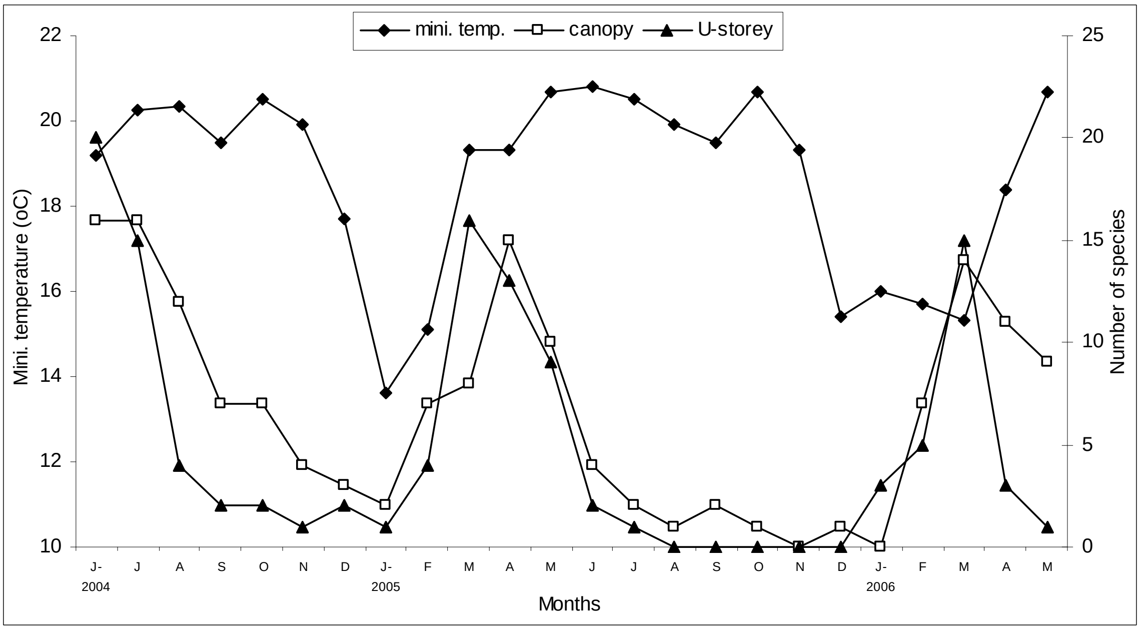

FIG. 6: LEAF INITIATION / LEAF BUDDING PHENOLOGY IN CANOPY AND UNDERSTOREY TREES WITH AVERAGE MINIMUM TEMPERATURE IN BHADRA WILDLIFE SANCTUARY.

Leaf Expansion Phenology

In canopy and understorey trees leaf expansion starts from February till July, as expansion to full leaf takes more time from summer to onset of rain. (Fig. 7)

Leaf expansion and rainfall is not significant during corresponding and one month lag period in canopy and

understorey trees, two months lag period is negatively significant (r_s = -0.45, p<0.03) and has a strong negative significance during three months lag period (r_s = -0.68, p<0.0005) in canopy trees and in understorey trees during two month (r_s = - 0.42, p<0.04) and three month (r_s = - 0.60, p<0.003) lag period has a negative influence. (Fig. 7)

In canopy trees maximum temperature has a positive influence during corresponding months (r_s = 0.45, p<0.02), one month lag period (r_s = 0.58, p <0.003) and two month lag period (r_s = 0.47, p<0.02). While in understorey trees maximum temperature has no influence during corresponding month. But during one month (r_s = 0.54, p<0.007) and two month (r_s = 0.47, p<0.02) lag period has a positively significant influence (Fig. 8).

Minimum temperature is not significant during corresponding and one month lag period in both canopy and understorey trees, but negatively significant (r_s = -0.51, p<0.01) during two month lag period and has a strong negative influence during three month lag period (r_s = -0.74, p<0.0001) in canopy trees, and understorey trees during two month (r_s = -0.51, p<0.01) lag period has a negative influence and has a strong influence during three month lag period (r_s = -0.80, p<0.00001).

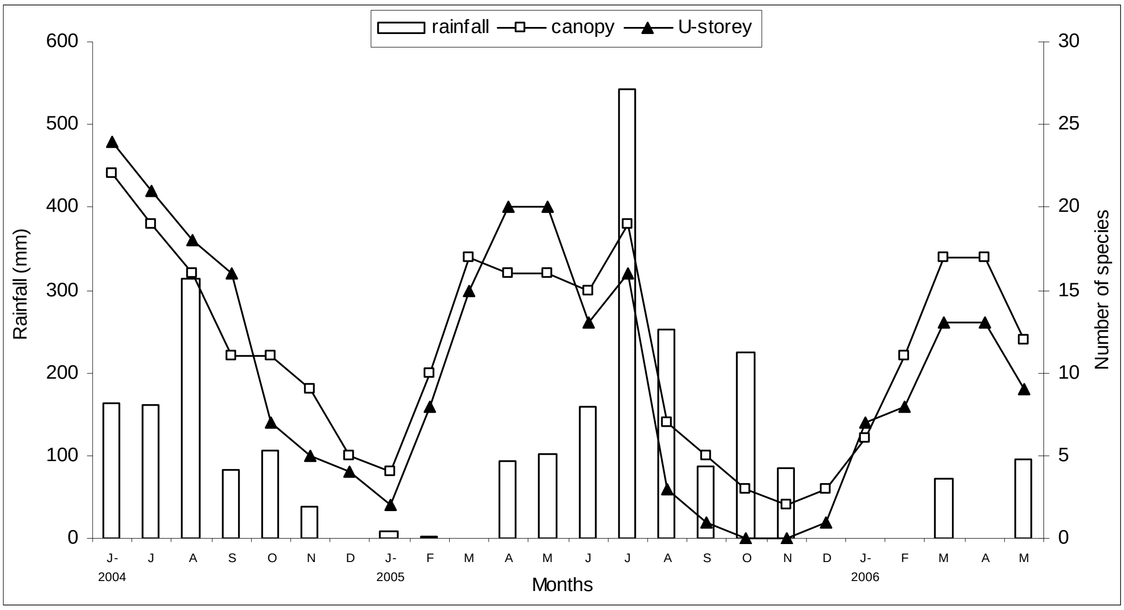

FIG. 7: LEAF EXPANSION / IMMATURE LEAFING PHENOLOGY IN CANOPY AND UNDERSTOREY TREES WITH AVERAGE MONTHLY RAINFALL IN BHADRA WILDLIFE SANCTUARY.

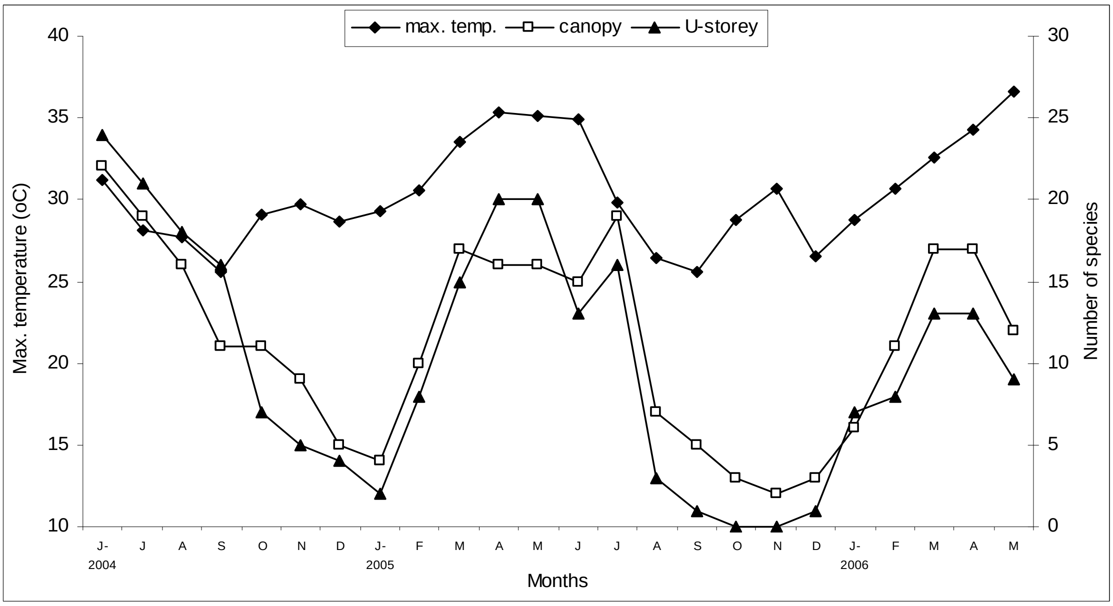

FIG. 8: LEAF EXPANSION / IMMATURE LEAFING PHENOLOGY IN CANOPY AND UNDERSTOREY TREES WITH AVERAGE MAXIMUM TEMPERATURE IN BHADRA WILDLIFE SANCTUARY.

Leaf Senescence / Leaf Falling Phenology

In canopy and understorey trees leaf senescence begins in November and peaks in December and January in both years with varying number of species. (Fig. 9)

In canopy trees, rainfall has a strong negative influence during corresponding months (r_s = -0.73, p<0.00005), and negative influence during one month lag period (r_s = -0.44, p<0.03). Whereas in understorey species, rainfall (r_s = -0.61, p<0.01) is negatively significant during corresponding and during one month lag period (r_s = -0.53, p<0.009).

Maximum temperature has no influence during corresponding months both in canopy and understorey trees. While during one month (r_s = -0.47, p<0.02), two months (r_s = -0.53, p<0.009) and three months lag period (r_s = -0.55, p<0.009) has a significant negative influence in canopy trees and in understorey trees during one month (r_s = -0.50, p<0.01), two months (r_s = -0.58, p<0.004) and three months (r_s = -0.57, p<0.006) lag period has a significant negative influence **(Fig. 9).** Minimum temperature in canopy trees (r_s = -0.68, p<0.0001) is negatively significant, in understorey trees has a strong negative influence during corresponding months (r_s = -0.73, p<0.00004). Minimum temperature has no significant influence during lag periods both in canopy and understorey trees (Fig. 10).

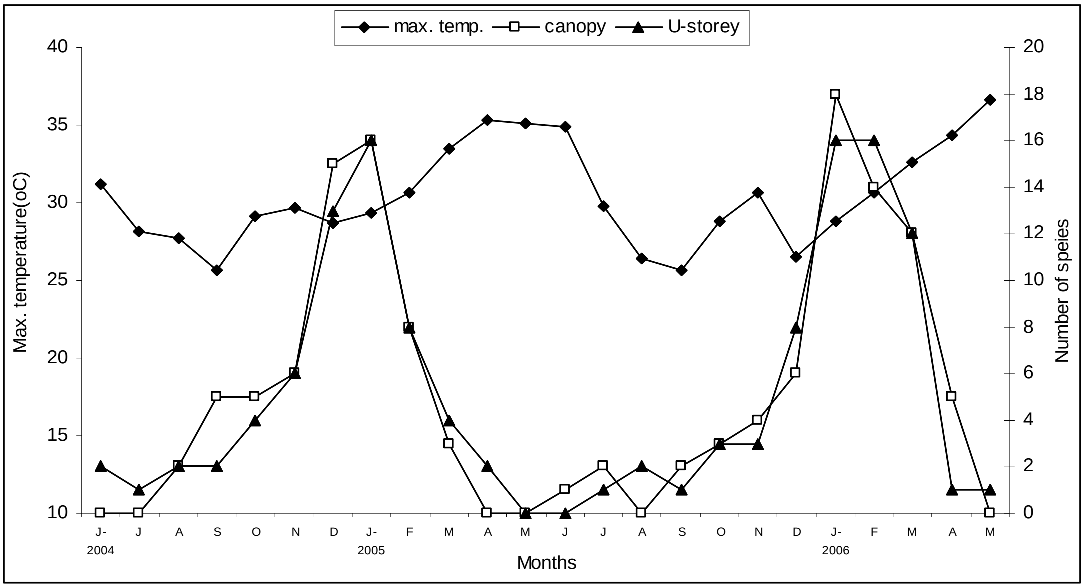

FIG. 9: LEAF FALLING / LEAF SENESCENCE PHENOLOGY IN CANOPY AND UNDERSTOREY TREES WITH AVERAGE MAXIMUM TEMPERATURE IN BHADRA WILDLIFE SANCTUARY.

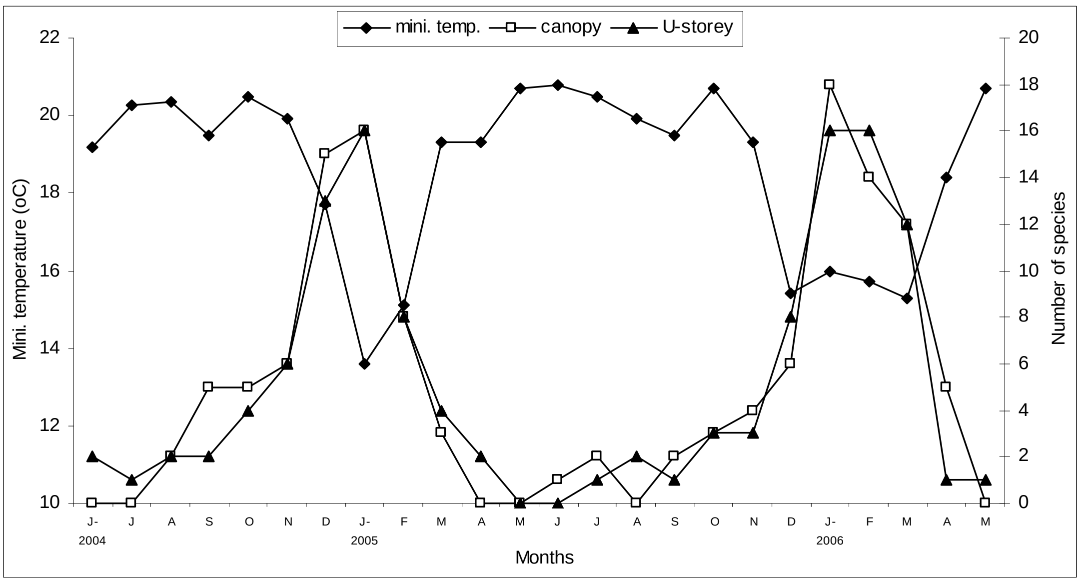

FIG. 10: LEAF FALLING / LEAF SENESCENCE PHENOLOGY IN CANOPY AND UNDERSTOREY TREES WITH AVERAGE MINIMUM TEMPERATURE IN BHADRA WILDLIFE SANCTUARY.

Seasonality of Canopy and Understorey Leaf Phenology –

Seasonality of leaf phenophases in canopy and understorey trees is strongly seasonal. Their leafing pattern and strength of the seasonality is indicated by the mean angle and mean vector.

Percent of canopy tree species, leafing phenology differs in two years (Fig.11). In dry deciduous forest most of the canopy trees like *Haldina cordifolia, Bombax malabaricum, Dalbergia latifolia, Terminalia paniculata, Anogeissus latifolia, Pterocarpus marsupium, Tectona grandis* and *Lagerstroemia lanceolata*. Leaf less occurs in the middle of the March month (72.25). Leaf initiation starts in the middle of the May month (136.0), leaf expansion in the end of the May month (146.0) and senescence in the middle of January month (15.95). The strength of seasonality measured by the mean vector indicates that leaf less phase (0.61) has strong seasonality followed by leaf senescence (0.58) leaf initiation (0.37) and leaf expansion (0.31) (Table 2).

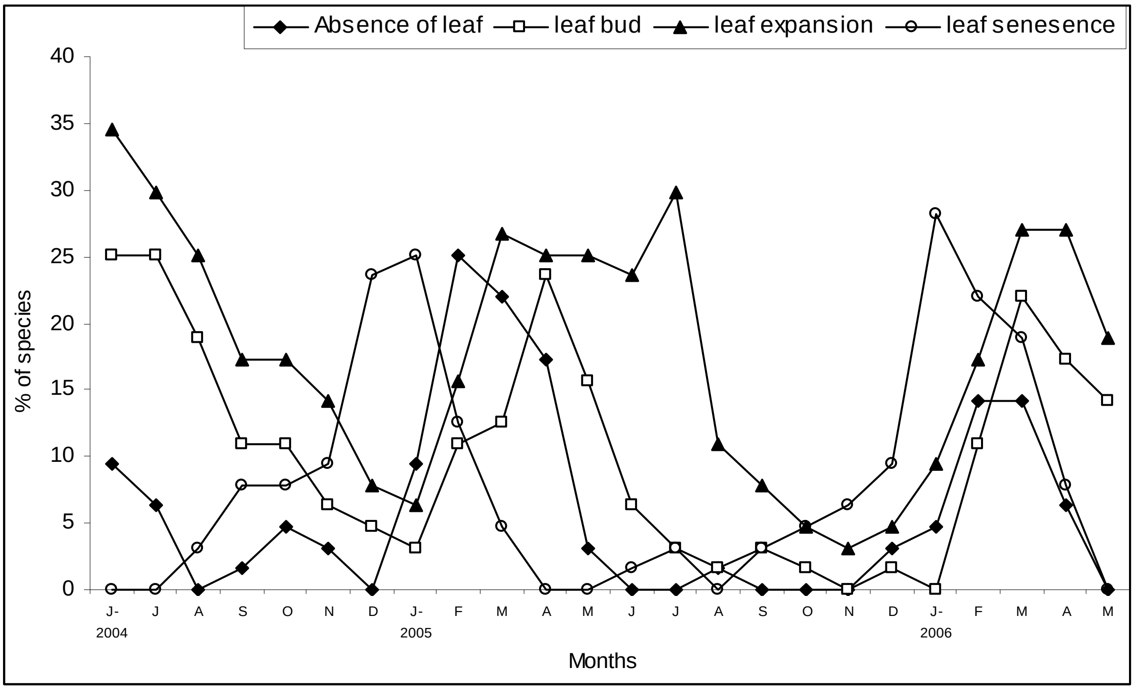

FIG. 11: PERCENT OF LEAF PHENOLOGY IN CANOPY TREES IN BHADRA WILDLIFE SANCTUARY.

TABLE 2. SEASONALITY OF THE LEAF PHENOPHASES OF CANOPY, UNDERSTOREY TREE SPECIES AT DRY DECIDUOUS FOREST OF BHADRA WILDLIFE SANCTUARY, KARNATAKA, INDIA.

Life-form (canopy – understorey)	Phenophases			
	Leafless	Leaf initiation	Leaf expansion	Leaf senescence
Mean angle	72.25 - 75.09	136.0 - 120.09	146.0 - 148.61	15.95 - 20.34
Mean Data	12 March – 15 March	16 May – 30 April	26 May – 29 May	16 January – 21 January
Mean vector r	0.61- 0.65	0.37 - 0.52	0.31 - 0.39	0.58 - 0.59
Angular SD	56.40 - 52.34	80.45 - 65.44	87.67 - 77.79	59.04 - 58.67
Rayleigh's Z	35.28 - 41.66	22.13 - 32.27	26.25 - 38.61	43.91 - 43.45
P value	<0.000*	<0.000*	<0.000*	<0.000*

*Significant at < 0.05

Percent of understorey tree species, leafing phenology differs in two years (Fig.12). In dry deciduous forest most of the understorey trees species like *Bassia latifolia, Careya arborea, Chloroxylon swietenia, Catunaregam spinosa, Semecarpus anacardium, Holarrhena antidysenterica,* and *Wrightia tinctoria*.

Leaf less in the middle of the March month (75.09), leaf initiation in the beginning of the May (120.09) followed by leaf expansion in the middle of the May (148.61) and leaf senescence in the middle of the January month (20.34). The strength of seasonality measured by the mean vector indicates that leaf less phase (0.65) has strongly seasonal followed by leaf senescence (0.59), leaf initiation (0.52) and leaf expansion (0.39). (Table 2)

At community level in understorey leaf initiation begins the first latter in canopy trees with a difference of 13-14 days, when canopy trees are in leaf less or leaf absence period, whereas leaf expansion and leaf senescence take place early in canopy trees, with a difference of 2 and 4 days. Absence of leaf peaks occurs in the middle of the March in canopy and understorey trees, with a difference of 3-5 days.

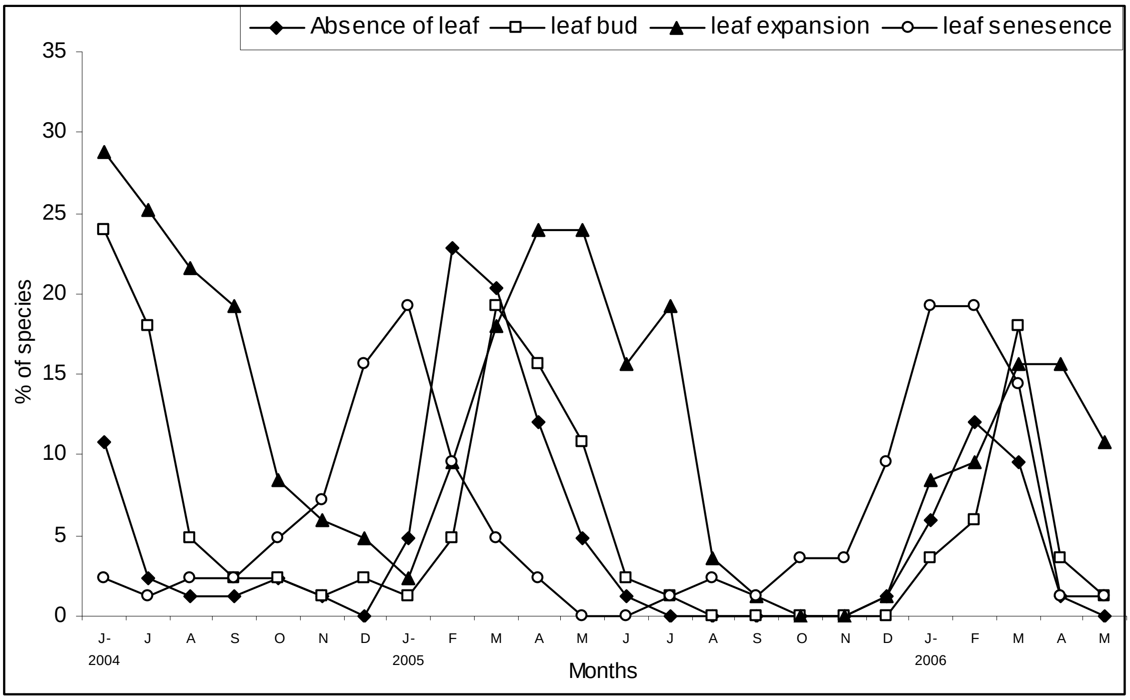

FIG. 12: PERCENT OF LEAF PHENOLOGY IN UNDERSTOREY TREES IN BHADRA WILDLIFE SANCTUARY.

Discussion

In canopy and understorey trees absence of leaf period begins in the month of January with a peak in February and March in the first year, whereas in the second year it starts one month early in December with a peak in February and March. Leaf initiation begins in February in one or the other species and gradually expansion to full leaf till July. Leaf senescence begins in November and peaks in December and January.

Leafing phenological patterns of tree species are expected to be sensitive to short-term fluctuations in rainfall and temperature. (Nanda *et al.* 2010). Leaf phenology duration mainly depends on the timing of leaf initiation, of individual species and the triggering factors like temperature, onset of rainfall and insolation as it varies with canopy and understorey trees in tropical forest types (Nanda *et al.* 2012).

Water stress in dry seasons strongly regulates the leaf phenology in tropical dry forests, with most of the leaves being dropped during dry seasons (Reich and Borchert 1984; Borchert 1994).

According to Lechowicz (1984) the initiation of tree leaf development has been related to the number of degree-days prior to leaf emergence. However, as leaf emergence occurs at cooler temperatures in northern sugar maple populations, other factors than degree-days alone control leaf emergence in this species. Raulier and Bernier (2000) recently proposed that a combination of chilling days and warming days could explain the date of leaf emergence in sugar maple populations.

Before canopy closure, understorey plants receive more light daily and have higher photosynthetic rates (Sparling 1967; Taylor and Pearcy 1976; Gill 1998). Therefore, the length of time available to understorey plants for carbon gain is largely determined by the foliar phenology of overstorey trees in deciduous forests (Seiwa 1998). For deciduous trees, the timings of leaf bud burst and leaf senescence defines canopy duration and thereby determines the timing of carbon assimilation (Baldocchi and Wilson 2001; Barr 2007; Keeling 1996). Understanding the processes behind leaf senescence is still a challenge. Though some of the implied molecular agents of senescence have been identified and related to stress-responses pathways (Lim 2007), environmental triggers and their

interactions are still far from clear. Several studies suggest low temperatures (e.g. daily mean temperature below a 8^{0}C threshold; Estrella and Menzel 2006) and short days (Addicott 1968; Koike 1990; with a 13-h photoperiod threshold by 63^{0}N latitude in Keskitalo 2005) to be among the main factors involved in triggering leaf senescence in deciduous trees. During the second year of observation, intensity of leaf flush was also varying among species. The number of species response in dry deciduous forest as well as evergreen forest leaf flush was less intense, as rainfall during second year (2005-06) was more compare to first year (2004-05). Therefore, factors other than rainfall may be involved in these patterns, probably including an internal regulation.

According (van Asch *et al*. 2007) to predict how phenologies will evolve in response to recent climate change remains limited. Even in some cases where evolutionary change is expected, based on trait heritabilities and selection pressures, adaptation is not observed.

At community level one or the other species leaf flushing continued in several months it indicates every species continued availability of new photosynthetically active sites (Singh and Singh 1992). The timing of leaf emergence is determined by the balance of carbon gain (Lockardt 1983; Loechowicz 1984). The majority of Indian tree species leaf flush occurs during the late dry season before the arrival of the monsoon rains, indicating that substantial subsoil water storage in old, deeply weathered soils permits spring-flushing during the late dry season (Elliot *et al*. 2006). Even in tropical rainforests magnitude of leaf flush and leaf fall peaks noticed with pronounced dry period (Hladik 1978). Dry period leaf flushing occurs because of environmental factors are favourable for maximizing photosynthesis (Salisbury and Ross 2004; Meyer 1960). Change in leafing pattern was noticed due to differences in temporal and spatial microsites, insolation to the forest floor (Justiniano and Frederickson 2000). Leaf flush with the onset of rain after a spell of dry period, as in Barro Colorado Island (Leigh and Windsor 1982) early in the dry season as in Costa Rica (Frankie 1974). Leaf flush soon after the onset of rains is the signaling of the end of unfavourable physiological period and beginning of a favourable growth period (Prasad and Hegde 1986) in Bandipur, Southern India. Leaf expansion duration in dry forest of Bhadra Sanctuary has taken one to four months, which varies with different species as *Anogeissus latifolia, Bassia latifolia* (Nanda *et al*. 2015). Leaf senescence starts in November and will be up to February with a peak in January both in canopy and understorey trees with a varying number of species. Leaf senescence as recorded in two seasons from winter when minimum temperature 19.9°C to summer season with a maximum temperature 35.3° C.

Asynchrony in leaf phenology in both canopy and understorey trees during the two annual cycles. Phenology of trees in dry tropics is mainly determined by the duration and intensity of seasonal drought. The degree of drought to which trees are exposed varies widely, depending on temperature and availability of soil water, and also tree characteristics such as rooting depth (Van Schaik 1993). Borchert (1998). There is increasing evidence that global climatic change is affecting species physiology, distribution and phenology of tropical forests.

Phylogenetic approaches can help to map both observational phenology data, as well as model estimates of how strongly species cue to different environmental variables such as temperature (Bolmgren and Cowan 2008; Willis *et al*. 2008; Davis *et al*. 2010). In addition, because phylogeny allows us to infer the evolutionary dynamics of trait changes it can also help address questions regarding the underlying physiological pathways that determine phenology. (Pau *et al*. 2011). Therefore phenology might map closely onto phylogeny, so that evolutionary divergence is a good predictor of difference in phenology (Willis *et al*. 2008). Phylogenetic approaches also provide a means to test for temporal niche differentiation in communities. For example, if closely related species share similar phenological traits, then at local spatial scales species may partition themselves through time to reduce competition (Webb 2000; Cavender-Bares *et al*. 2004).

Conclusion

In this study we made an attempt to assess the short term fluctuation in leafing phenophases intensity and duration in relation to total rainfall mean maximum and minimum temperature, as timing of one phenophase influences other. These types of assessment or data help us for the better understanding and function of tropical forests. As changes in phenological events have the potential to broadly impact terrestrial ecosystem, by altering global carbon, water, insect damage and disease. Finally it is important to coordinate long term studies to further the understanding of phenological patterns of tropical trees and the cues that trigger them.

In contrast, the evolutionary lability of phenology can be limited because life-history traits are subject to certain unavoidable constraints.

ACKNOWLEDGMENT

I thank Department of Environment, Ministry for Environment and Forests, Government of India for financial support project No.14/10/2001-ERS-RE, 2003 as a research fellowship for the first author. Thanks to Forest department of Karnataka for permission to work in Bhadra wildlife sanctuary, and the Bhadra River Project meteorological station for data on rainfall and temperature.

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